AMENDMENTS TO THE SPECIFICATION

Please amend the specification as follows:

On page 7, replace the first full paragraph with the following:

Referring to Figures 2, 3A, and 3B, dispensing device 100 pursuant to an illustrative embodiment of the invention is shown schematically as comprising a semiconductor chip substrate C on which the dispensing device is fabricated by micromachining techniques as described below. The dispensing device 100 comprises one or more elongated cantilevers 102 that each comprise a plurality of thin films arranged relative to one another as described below to define an elongated cantilever body having a microchannel 104 therein and to define a material-dispensing working microtip 106 proximate an end of each cantilever remote from the chip substrate C. Each microtip 106 ~~is communicated~~ communicates with a respective microchannel 104 to receive material M therefrom to be dispensed from the microtip onto the surface S. In turn, each microchannel 104 ~~is communicated to~~ communicates with a common material-containing reservoir 108 that supplies material M to the microchannel, although each microchannel may ~~be communicated to~~ communicate with its own respective material-containing reservoir. In Figure 3B, the fluid dispensing microtip 106 is shown comprising a pointed core tip body 107 having a radius R and an annular, generally truncated conical converging shell 109 spaced about the core tip to define a material dispensing annular space or annulus 110 residing about the core tip. The shell 109 converges in a direction toward the apex of the core tip body 107. To provide control of equilibrium of the fluid-air interface at the

annulus 110, the core tip body 107 preferably comprises hydrophilic material (e.g. silicon nitride, silicon oxide, metals) and the shell 109 preferably comprises an equal or less hydrophilic material (e.g. silicon nitride, silicon, doped silicon).

On page 7, replace the last paragraph with the following:

Referring to Figures 4A, 4B, 5 and 6 which represent a device layout to be fabricated on the chip C for a particular exemplary embodiment of the invention, the microchannels 104 are shown having first and second ~~side- by-side~~ side-by-side channel regions 112a, 112b (see Figure 6) separated by a wall 113 with the channel regions ~~104a, 104b~~ 112a, 112b terminating in a common arcuate channel region ~~104c~~ 112c extending partially about the core tip body 107 to supply material thereto from the reservoir 108. In Figures 4A, 4B, 5 and 6, five cantilevers 102 of different lengths (e.g. from 300 microns to 500 microns with cantilever stiffness of 0.05 to 0.4 N/m) were formed extending from the chip C to evaluate cantilever length

On page 8, replace lines 1-3 with the following:

effects. The microchannels in the cantilevers 102 had a width of [[4]] four to [[7]] seven microns while the tip 107 had a height of ~~3-5~~ three to five microns relative to the surface of the adjacent cantilever 102 for demonstration purposes.

On page 10, replace the fourth paragraph with the following:

~~Figures~~ Figure 9A illustrates partial etching of the $SiO_2$ layer 132 that occurs to form open sided microchannel regions ~~104a, 104b~~ 112a, 112b separated by and on opposite sides of wall 113 on each cantilever 102 concurrently with formation of the undercuts 138, 140, 141 of Figure 8C.

On page 11, replace the first paragraph with the following:

Then, the selective oxidation step is followed by deposition of a sealing layer 142 by sputtering, or evaporation or CVD process as illustrated in Figure 8D along lines B-B′ and in Figure 9C. The sealing layer 142 can comprise $Si_3N_4$ or polycrystalline silicon (Poly-Si) sealing material, or any other suitable sealing material. The sealing layer 142 overlies the outermost edges of the first and third films as shown best in Figure 9C to prevent leakage of fluid or material from the microchannel regions ~~104a, 104b~~ 112a, 112b. Figure 10 is a photomicrograph of a cantilever 102 after the sealing layer 142 is deposited thereon as illustrated in Figures 9A through 9C, which are taken along lines A-A′ of Figure 10[[.]].

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On page 11, replace the third paragraph with the following:

Then, the exposed apex of the microtip, starting with the sealing layer and continued with the third layer, ~~are~~ is etched by $CF_4$ RIE, Figure 8G. The remaining photoresist is removed by oxygen plasma. The selective removal by buffered hydrofluoric solution of the second thin film or layer 132 of $SiO_2$ from between the first and third films or layers 130, 134 at the core tip body 107, Figure 8H, occurs until the annular space or annulus 110 so formed communicates with the microchannel. This completes the formation of the volcano-shaped microtip 106, Figure 8I which is taken along lines ~~A'A'~~ A-A' of Figure 5. The microtip 106 thereby is formed to include pointed core tip body 107 and an annular, generally conical converging shell 109 (comprised of the third film or layer 134) spaced about the core tip body to define a material dispensing annular space or annulus 110 residing about the core tip body. The sealing layer 142 resides on the conical converging shell 109. Figures 8J and 8K are photomicrographs of cantilevers and a microtip prior to release from the chip substrate.

On page 12, replace lines 1-8 with the following:

backside release mask eventually contains convex corner compensation beams such as described in Sensors and Actuators, ~~Vol.3~~ Vol. 3, p.127, 1992, incorporated herein by reference. KOH etching involves wet etching of the chip substrate using 40% (mass ratio) KOH at 80 degrees C. Subsequently, the side of the chip opposing the tip will be coated by evaporation with a reflective metal film, such as Au (gold) 15 nm, to provide better reflection of the laser beam eventually used for the AFM

head positioning control (optical lever). The dispensing device 100 of Figure 3A is thereby microfabricated on the silicon substrate chip.

On page 12, replace the first full paragraph with the following:

For purposes of illustration and not limitation, the microfabrication method described above can be used to produce individual cantilevers 102 having a length of about 100 microns to about 500 microns and including a microchannel 102 having a width dimension in the range of about [[4]] four to about [[10]] ten microns and a height dimension in the range of about 0.05 to about 1.5 microns. Flow rate of fluid through a microchannel is affected by channel dimensions, fluid wetting properties of the microtip and materials of the microtip and microchannel, the chemical ~~pretreatement~~ pretreatment, and fluid viscosity. Similarly, the core tip body 107 can be produced to have an apex having a height of about [[3]] three to about [[5]] five microns of the tip relative to a plane of the cantilever (0.5 to 1.5 microns above the plane defined by the end of the shell 109). The inner radius of the end of the shell 109 measured from the apex of the core tip body 107 can be in the range of 0.5 to 2 microns.

On page 12, replace the last paragraph with the following:

Figures 11A through 11D illustrate an alternative embodiment for forming the microtip wherein like reference numerals are used to designate like features of previous figures. In Figure 11A, the core top body 107 is illustrated as having been doped with boron (B) which doped region BR functions as an etch stop during later KOH etching step for the release of the cantilever illustrated in ~~Figures~~ Figure 11E, to form the volcano-shaped microtip 106 differing from that of ~~Figure~~ Figures 3A and 8I in having a pointed end 107t of the boron doped core tip body 107 protruding above the first thin film or layer 130 of $Si_3N_4$ as shown in ~~Figure~~ Figures 11D and 11E. Such a microtip of ~~Figure~~ Figures 11D-11E permits two possible configurations for the fluid-air interface at the microtip 106 as illustrated in Figures 12A, 12B, respectively. A pressure pulse of about [[1]] one atmosphere on the fluid is needed to switch from the fluid-air interface of Figure 12A to that of Figure 12B. An

On page 13, replace lines 1-2 with the following:

alternative way to bring the fluid interface to that of Figure 12B is to dip the dispensing tip into liquid.

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On page 13, replace the first paragraph with the following:

Figures 13A, 13B, 13C illustrate an alternative embodiment for sealing of the longitudinal edge or side E of a microchannel regions ~~104a, 104b~~ 112a, 112b defined between the first and third thin films or layers 130, 134 of $Si_3N_4$ and separated by wall 113 formed by partially etching the second thin film or layer 132 of $SiO_2$. In this alternative embodiment, the sealing layer 142 is deposited in the microchannel regions ~~104a, 104b~~ 112a, 112b. For example, referring to Figure 13B, during the selective oxidation step where the chip substrate C is oxidized at areas OX ($SiO_2$), both the first and third thin films or layers 130, 134 have been observed to bend slightly away from the chip substrate so as to have angled ~~region s~~ regions 130a, 134a at [[an]] outermost edges thereof. A small gap is formed between the angled regions 130a, 134a, as illustrated in Figure 13B. Subsequent deposition of the sealing layer 142 by LPCVD has been found to result in deposition of the sealing layer 142 on the surfaces inside the microchannel regions ~~104a, 104b~~ 112a, 112b as illustrated in Figure 13C (before etching of the substrate chip) and Figure 13D (after etching of the chip substrate) to effect sealing of the microchannel regions. The internal deposition of the sealing layer on the inner walls of the microchannels does not reduce substantially the cross section and the fluid transport in the channels, since there is a fluid transport (flow) only during the filling of the microchannel, not during the writing process, which relies mostly on the diffusion of ink molecular species along the channels, rather than a flow of the fluid ink itself. However, the deposition of the sealing layer on the inner sidewall of the microchannels may

hinder the establishing of the connectivity between the microchannel and the shell-to-core gap 110 of the dispensing tip, during the etching step illustrated in Figure 8I. Figure 13E is a photomicrograph [[of]] showing the sealing layer deposited inside the microchannel regions of an actual microfabricated cantilever that has been transversely sectioned by a focused ion beam. Figure 13F is a photomicrograph [[of]] showing the sealed microchannel regions of an actual microfabricated microtip that has been transversely sectioned through the microtip. Figure 13G is a photomicrograph [[of]] showing the sealing layer deposited inside the microchannel regions around the core tip of an actual microfabricated microtip that has been transversely sectioned by focused ion beam along the dotted line of Figure 13F. Thus, the fabrication method described by

On page 14, replace lines 1-2 with the following:

~~Figure~~ Figures 8A-8I typically [[is]] are used only for sealing layers deposited by low conformity processes, such as evaporation and sputtering.

On page 14, replace the first full paragraph with the following:

Figures 14A, 14B, 14C illustrate still another alternative embodiment for sealing of the longitudinal edge or side of a microchannel regions ~~104a, 104b~~ 112a, 112b defined between the first and third thin films or layers 130, 134 of $Si_3N_4$ by wall 113 formed by partially etching the second thin film or layer 132 of $SiO_2$. This embodiment addresses the case the sealing is performed by depositing the sealing layer by a high conformity process, such as CVD. In this alternative embodiment, the first thin film or layer 130 comprises a low stress SiN layer and the third thin film or layer 134 is modified to comprise a dual layer structure comprising a low stress SiN layer 134s and high stress SiN layer 134t that bends in response to residual internal stress toward the first thin layer or film 130 [[to]], as shown in Figure 14A, to reduce the size of the gap at the outermost edges of these films or layers. A low stress SiN film or layer is deposited by LPCVD (low stress nitride process, based on higher Si content in the film and higher deposition temperatures, such as 875 degrees C),while a high stress SiN is deposited by standard LPCVD ~~stoicihiometric~~ stoichiometric nitride deposition process.

On page 14, replace the second paragraph with the following:

Figure 14B shows the effect of selective oxidation of the chip substrate C to cause the first film or layer 130 to bend toward the third film or layer 134 to form an outermost angled region 130a at an outmost edge thereof concurrently with the selective oxidation. A low stress SiN sealing layer 142 then is deposited on the third thin film or layer 134 to seal the

smaller gap with reduced penetration of the sealing layer into the microchannel regions ~~104a, 104b~~ 112a, 112b, Figure 14C. Figure 14D is a photomicrograph [[of]] showing the sealing layer deposited partially inside the microchannel regions of an actual microfabricated cantilever that has been transversely sectioned.

On page 14, replace the last paragraph with the following:

~~Figure~~ Figures 15A through 15Y (where like features of previous figures are designated by like reference numerals) illustrate an embodiment of the invention in which a sharper tip is microfabricated on a cantilever 102 and the connectivity (communication) of the microchannels 104 to the shell-to-core annular space 110 of the dispensing tip is increased, to work with a subsequent high conformity sealing layer deposition, leading to improved sealing of the microchannels.

On page 15, replace the first paragraph with the following:

Figures 15A through 15B illustrate a microfabrication method for forming a sharp tip body 107 by depositing a masking layer 200, patterning it by lithographic means and etching the silicon substrate isotropically, followed by oxidation sharpening (this process reproduces the previous process described in Figure 8A). Figure 15C illustrates the lithographic removal of the oxide 202 around the tip body 107 by wet etching, such as using buffered hydrofluoric acid and the ion implantation of an etch stop dopant, such as boron $5 \times 10^{19}$ B/cm$^3$, to form an implanted tip body region BR followed by the removal of the oxide by buffered hydrofluoric acid, Figure 15D. Then, a

first thin film layer 130, such as low stress silicon nitride of thickness from 0.25 μm to 1 μm, and a temporary masking layer 206, such as oxide of thickness from 0.25 μm to 0.5 μm, are deposited by LPCVD methods. A lithographic mask 208 is applied to define an exposed region around the tip body 107 that is 1-4 μm[[.]] less in radial size than the ion implanted region BR and also defining simultaneously the shape of the future reservoir, Figure 15E. The temporary masking layer 206, such as oxide, is wet etched using buffered hydrofluoric acid in the openings of the photoresist mask, Figure 15F. The photoresist is removed, and the first layer 130, such as nitride, is wet etched to expose the pointed tip 107t on the substrate C, such as using hot phosphoric acid in the openings provided by the temporary masking layer 206, Figure 15G. Then, the temporary masking layer 206, such as oxide, is removed by buffered hydrofluoric acid, Figure 15H. Then, a second thin film layer 132, such as low temperature silicon oxide, and a third thin film layer 134, such as low stress silicon nitride, are deposited on the substrate by LPCVD, Figure 15I, and patterned lithographically to define the shape of the cantilever precursor and future channels, Figure 15J. The third thin film layer 134 can eventually be a sandwich of high stress nitride and low stress nitride, such as in the process described in ~~Figure~~ Figures 13A-13D, to provide later a better sealing by bending the third thin film layer 134 towards the first thin film layer 130. The third, second and first thin film layers are etched through the lithographic mask 210, using reactive ion etching, such as with $CF_4$ gas, Figure 15K. Then, a selective wet chemical etching of the second thin film layer 132 is performed, such as by using buffered hydrofluoric acid, to define concurrently the open-side microchannels 104 and shell-

to-tip annular space 110 of the dispensing microtip 106, Figure 15L. The etching of the second thin film layer 132 at this step is to be performed

On page 16, replace lines 1-31 with the following:

until the second thin film layer is etched around the apex of the tip body 107. If the desired width of the microchannels 104 is etched before the second thin film layer is etched away around the apex of the tip body 107, an additional lithographic mask 214 can be applied and the second thin film layer etching can be subsequently continued locally, only around the tip body 107, as illustrated in Figure 15M. After the etching of the second thin film layer 132 is conducted to form the desired size of microchannels 104 and shell-to-core annular space 110 at the dispensing tip, a thermal oxidation of the silicon chip C at area OX for example is performed, Figure 15N, to provide an angling of the first thin film layer 130 so as to close the gap or space at the outermost edges of the microchannel 104, through a process known as "birds beak oxidation" for those skilled in the field and/or as described above with respect to Figures 9A-9C, 13A-13D, and 14A-14D. Subsequently, a sealing layer 142, including but not limited, to a low stress silicon nitride is deposited by any deposition method, including but not limited to LPCVD. In case of a deposition method of high conformity, such as LPCVD, the sealing layer 142 may cover the inner surfaces of the microchannels 104 and the annular space 110 around the tip body 107, without affecting their future fluid communication, Figure 15P. The device microfabrication continues by defining

the future cantilever shape lithographically, Figure 15Q, via patterning with photoresist 216 of the sealing layer 142, using a selective etching such as like $CF_4$ RIE in case the sealing layer is silicon nitride. The same photoresist layer or another photoresist layer can be used to first decover the tip apex 107t by thinning the photoresist with oxygen plasma etching, then to continue with reactive ion etching (such as $CF_4$ RIE) to etch the sealing layer 142 and the third thin film layer 134 around the tip apex 107t, ~~Figure~~ Figures 15S and 15T which also present the schematic evolution of the tip shape during the etching process. After the complete removal of the photoresist by using oxygen plasma or/and commercial photoresist remover, the device structure appears as shown in Figure 15T. Then, the backside alignment and lithography are performed, eventually using a mask containing convex corner compensation beams, such as the one in Figure 8L. The backside masking layer corresponds to the first, second, third and sealing thin film layers, which can be removed sequentially using reactive ion etching, such as $CF_4$ RIE[[.]], or combinations of RIE and wet chemical etching, Figure 15U. Then, a backside silicon etching of the silicon chip substrate C is performed using a front-

On page 17, replace lines 1-16 with the following:

side protecting holder and 40% (mass ratio) KOH solution at 80 degrees C, or any other method of etching of the silicon chip substrate while protecting the structures on the front side of the chip ~~substrate ,~~ substrate, Figure 15V. The backside silicon removal step also defines the reservoir 108 and the chip substrate C eventually mechanically attached to a larger silicon frame for easy handling, while leaving the cantilever structure embedded in a composite membrane composed of oxide, the first, second, third and the sealing thin film layers, out of which the oxide and the second thin film layer are subsequently wet-etched, such as using buffered hydrofluoric acid, Figure 15X. If necessary, the backside of the chip substrate can be further etched using $CF_4$ RIE to connect the microchannels 104 to the reservoir 108 by removing the sealing layer 142 eventually covering the inner side surfaces of the microchannels. A very thin metal layer, such as including but not limited to Au 15 nm, can be deposited on the backside of the chip substrate C in order to increase the reflection of the cantilever 102 for the laser beam eventually used for the control of the AFM probe positioning (optical lever). Use of the fabricated device and microtip to write or probe is achieved with the tip oriented towards the writing or probing surface S as illustrated in Figure 15Y.

On page 17, replace the last paragraph with following:

Figures 16A, 16B and 17, 17A illustrate an embodiment of the invention wherein an actuator 150 is disposed on each cantilever 102 to impart bending motion thereto to move the microtip 106 close enough to the surface S to ~~effect~~ dispense writing material thereon, or in an embodiment where no material is dispensed, close enough to probe surface S or to apply or record an electrical signal on surface S. The actuator 150 may be selected from any suitable actuator, such as including, but not limited to, a piezoelectric actuator having a piezoelectric film, a thermal actuator having a resistor forming a composite with the rest of the cantilever, with different thermal expansion coefficients, or a magnetic actuator having a magnetic film and others.

On page 18, replace the first paragraph with following:

Referring to Figures 16A, 16B, a piezoelectric actuator 150 is illustrated as being formed on the surface of the cantilever 102 on which the microtip 106 is disposed. The piezoelectric actuator 150 is formed by depositing on that surface a Pt film 152 sandwiched between the Ti films, a piezoelectric (PZT) film 154, and a Au (gold) film 158 separated by a Ti film from the PZT film. The Pt film 152 provides an electrical contact by which the PZT film 154 is connected by electrical lead 160 to ground, and the Au film 158 provides an electrical contact by which the PZT film 154 is connected by electrical lead 162 to a source of electrical voltage or current (not shown) to energize the piezoelectric film 154 in a manner to cause the cantilever

102 to bend toward or away from the surface S. Each actuator 150 thereby can be addressed and actuated independently by a suitable electronic controller, such as a microcomputer (not shown), to independently actuate the cantilevers 102 to move during operation of the dispensing device 100. The first-deposited Pt film can be used eventually also as a reflective layer for enhancing the reflection properties of the cantilever for optical position control within the AFM equipment (optical lever).

On page 18, replace the last paragraph with following:

Figure 17 illustrates schematically fabrication of a dispensing device ~~200~~ 200′ having a plurality of cantilevers 102 of the type described above integrated in linear and two dimensional arrays as shown for purposes of illustration and not limitation. The device ~~200~~ 200′ is shown including one common reservoir 108 to supply material to all of the cantilevers 102 but more than one reservoir 108 can be provided as desired. For example, a reservoir 108′ could be provided for each row of cantilevers. Each cantilever 102 includes a PZT actuator 150 that is addressed and actuated independently by a suitable controller (not shown). Figures 17A shows a cantilever 102 with the actuator 150 thereon. Those skilled in the art will appreciate that one or more other devices ~~200~~ 200′ can be stacked atop and/or below the device ~~200~~ 200′ shown to provide stacks of two dimensional cantilevers 102 arrays in a manner to form a three dimensional cantilever array where the cantilevers are independently addressed and actuated by respective integral actuators 150 on the cantilevers 102 in response to a

multiplexed addressing scheme. Such arrays can be used to produce massively parallel active cantilevers for material (e.g. ink, biomolecules, etc.) dispensing applications with continuous-material delivery or feed to material dispensing microtips 106 for high speed direct writing over large surface areas.

On page 19, replace the second paragraph with following:

The invention envisions a method of applying an electrical stimulus and measuring the electrical response of a surface in nanometer-scale vicinity of a probing microtip 106 in the presence of a locally created environment at the end of the microtip through which the material is dispensed around the microtip. For example, an electrolyte material, such as including but not limited to, HCl, NaCl, copper sulfate, and the like, can be dispensed from the volcano-shaped microtip 106 of the cantilever 102 onto the surface to create the local environment. The electrical stimulus can be a constant or varying voltage or electrical current applied by the microtip 106 to the surface by appropriate movement of the cantilever 102 to bring the microtip close enough to or in contact with the electrolyte and/or the surface to apply the electrical stimulus thereto or to record an electrical response at a given location on the surface.~~The~~ The method can be used to characterize the dispensed material or the surface at the given location.

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On page 20, replace the last paragraph with following:

Although the invention has been described in connection with certain embodiments thereof, those skilled in the art will appreciate that the modifications and changes can be made thereto without departing ~~form~~ from the spirit and scope of the invention as set forth in the appended claims.